# EFFECTS OF OPERATING CONDITIONS ON ELECTRODIALYTIC CONCENTRATION OF SILVER FROM PHOTO-PROCESSING EFFLUENTS

By

P. D.C. BOTHEJU

THIS THESIS WAS SUBMITTED TO THE DEPARTMENT OF CIVIL ENGINEERING OF THE UNIVERSITY OF MORATUWA IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE DEGREE OF
MASTER OF SCIENCE.



DEPARTMENT OF CIVIL ENGINEERING
UNIVERSITY OF MORATUWA
MORATUWA
SRI LANKA



JULY 2005

# DECLARATION

I certify that this dissertation does not incorporate without acknowledgement of any material previously submitted for a Degree or Diploma in any University and to the best of my knowledge and belief it does not contain any material previously published or written or orally communicated by another person except, where due references is made in the text.

..........................................
P.D.C. Botheju

Admission No: 03 / 8008

Certified by



..........................................
Dr M.W. Jayaweera
Supervisor

# ABSTRACT

Electrodialysis is now recognized as a cleaner technology for reclaiming waste chemical solutions including industrial effluents contaminated with heavy metals. Compared with the conventional separation methods (chemical precipitation, filtration, evaporation, electrolysis, etc.), electrodialysis offers remarkable advantages such as less area requirement, ability to incorporate into the production process itself, avoidance of the generation of hazardous chemical sludge and many more. In this study, Electrodialytic recovery of Silver (Ag) from photo-processing effluents was investigated with the aim of understanding the possible effects of various operating conditions on the process.

In this study a laboratory fabricated four-membrane, five-compartment, Electrodialysis cell was used with the cationic and anionic selective ion exchange membranes Asahi Kasei K501SB and A501SB, respectively, which are originally used for seawater desalination. The removal efficiency of $Ag^+$ at different current densities was studied, using synthetically prepared metal ion solutions and actual industrial effluents containing Silver (photo processing effluents). Time dependent sampling was done and analyzed with a flame atomic absorption spectrophotometer (GBC 932).

According to the experimental results, very significant removal efficiencies were observed in the range of current densities studied. At low current densities of 2 and 4 mA/cm$^2$, removal percentages observed were 36 and 53.5, respectively. However at high current densities of 8 and 10 mA/cm$^2$, removal percentages increased up to 85 and 96 respectively (for an initial feed concentration of 1000 mg/L). However at those high current densities, ion exchange membranes were found to be damaged due to high heat dissipation. It was also noticed that at low concentrations of feed solution (i.e. 300 and 100 mg/L), the removal efficiencies were reduced remarkably. Considering these results Electrodialysis with the aid of desalination ion exchange membranes could be recognized as an efficient and locally made sustainable technology for treating silver containing effluents having a sufficiently high contamination level, while reclaiming the metal silver for reuse. However the necessity of a final smoothing treatment stage such as metal replacement, ion exchange or adsorption is stressed to obtain higher quality water.

Few experimental trials on Electrowinning were also conducted at a single electrical potential (5V), in order to compare the power consumption of the two processes. Results revealed that

the power consumption for electrodialysis is comparatively lower than electrowinning (i.e. by only considering the power consumption of the reactor, without accessories).

Necessity of the construction of pilot scale reactors is recognized for a full economical review of the two process schemes. On the other hand experiments must be carried out on the synthesis of ion exchange membranes having good permselectivity towards multivalent cations, so that the Electrodialysis process could be applicable on treating other industrial effluents contaminated with multivalent metal cations.

# ACKNOWLEDGEMENT

I would like to first express my deepest gratitude to Dr. Mahesh W. Jayaweera, Senior Lecturer, Department of Civil Engineering, University of Moratuwa, for being one of my supervisors and granting me all necessities and advising me in all aspects.

I am very much grateful and thankful to Dr. Suren Wijeyakoon, Senior Lecturer, Department of Chemical and Process Engineering, University of Moratuwa, for being my main supervisor, and guiding me in all aspects of this research study.

My warmest thank goes to Dr. D.M.D.O.K. Dissanayake, Senior Lecturer, Department of Earth Resources Engineering, University of Moratuwa, for the valuable comments and suggestions given as a supervisor.

Dr, Ajith de. Alwis and Dr. Shantha Walpolage must be specially mentioned for their valuable advice and encouragement given me for making this study a success.

I am indebted to SIDA (Swedish International Development Cooperation Agency) for funding my research project.

All the other academic and non academic staffs of the Departments of Civil, Chemical and Earth Resources Engineering are reminded with heartful of thanks for their strenuous support given to me in various occasions.



Credit must be given to Mrs. Nilanthi Gunathilake, Ms Priyanka Dissanayake, Ms Rukma, Ms. Rukshani and Mr. Justin for their great support rendered in undertaking chemical analysis and other laboratory work.

I would also like to thank Mr. Kithsiri Perera, for his kind support granted for preparing some experimental arrangements.

All the other colleagues of mine in the Environmental Engineering Laboratory of the Department of Civil Engineering, namely, Dayani, Sudesh, Kolitha, Sumudu, Anusha are warmly reminded, since their help and assistance given to me in various ways were remarkable.

A Special thank goes to Mr. Ranil Kularathna for his support in checking the proof of this thesis.

# CONTENTS

# LIST OF TABLES

# LIST OF FIGURES

## ABBREVIATIONS

| | | |
|---|---|---|
| AAS | - | Atomic Absorption Spectrophotometer |
| AEM | - | Anion Exchange Membrane |
| BPM | - | Bipolar Membranes |
| c.d | - | Current Density |
| CEM | - | Cation Exchange Membrane |
| DC | - | Direct Current |
| ED | - | Electrodialysis |
| EDI | - | Electrodeionization |
| EDR | - | Electrodialysis Reversal |
| EDTA | - | Ethylenediaminetetraacetic acid |
| EN | - | Electroless Nickel |
| HSA | - | High Surface Area |
| HMT | - | High Mass Transfer |
| HDPE | - | High Density Polyethylene |
| IEC | - | Ion Exchange Capacity |
| OSHA | - | US Occupational Safety and Health Administration |
| SS | - | Stainless Steel |
| USEPA | - | United States Environmental Protection Agency |